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PAC-3 MISSILE 30-YEAR LIFE CYCLE AND STREAMLINING

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## **I. INTRODUCTION**

This report will provide an overview of the problems, approaches, and solutions applied to developing a product assurance program for the PATRIOT Advanced Capability 3 (PAC-3) missile. The PAC-3 missile system requires hit-to-kill capability and is being developed/procured under acquisition streamlining. The performance and acquisition requirements for the PAC-3 missile system have presented unique challenges in managing and directing the program. This report will show the background and approach utilized by the PATRIOT Project Office (PPO) to meet these challenges and will demonstrate the steps being taken to assure that the PAC-3 missile is reliable and durable for its expected 30-year life.

## **II. PURPOSE**

The initial questions which must be answered by Product Assurance are:

- What kind of Product Assurance Program is required to develop a missile that will have a useful life of 30-years?
- How will reliability requirements for the missile be established?
- What are the loads/stresses/environments that the missile will likely experience in its 30-year lifetime?
- How will the reliability requirements be verified?

The purpose of this report is to answer these questions and to identify the problems, issues, and challenges that have been encountered or that are anticipated in managing and developing a highly reliable PAC-3 missile that will perform adequately for its projected 30-year life span.

### III. BACKGROUND

**With development and deployment of the PAC-3 missile, the DOD will enter a new era in precision missilery.** The ultimate performance requirement for the PAC-3 missile system will be to execute a single shot kill. This single shot must hit the "sweet spot" of the target with little error at tremendous closing velocities. The probability of a single shot kill is defined as the missile lethality multiplied by the missile reliability. Missile reliability is based on the combination of: flight reliability, on-launcher reliability and long-term storage reliability.

Assuring the lethality of a hit-to-kill missile requires an intensive management and technical effort involving every aspect of the development process, including systems engineering, hardware, software, production, product assurance, logistics, and programmatics. The challenge to those who are working the missile lethality issues is to achieve an acceptable lethality in the demanding "hit-to-kill" performance environment.

With respect to reliability, the efforts required to assure that the missile will be reliable when called upon any time during its 30-year life are significant and complex. While the issues of assuring in-flight missile reliability are significant, there are also reliability issues that go beyond the flight scenario. Considerations must include effects caused by long-term storage. Transport modes impart distinct consequences. Environment extremes must be characterized for on-launcher exposures for all geographic deployment zones. The effects of these loads/stresses/environments on missile reliability will be factored.

**"Streamlined" Product Assurance Program.** The U. S. Army Aviation and Missile Command (AMCOM), Program Executive Office Air and Missile Defense (PEO-AMD), and Lockheed Martin Vought Systems have an exceptional track record in the development and fielding of reliable missile systems. This excellence was achieved by diligently working complex issues and applying lessons learned. The PAC-3 missile program will be the beneficiary of this past experience. However, the PAC-3 missile has had to face new and unique challenges. Acquisition streamlining created a new era for **Change**. This change presented challenges in implementation since both Government and industry had to develop "new ways of doing business." Consequently, there were a lot of questions regarding streamlining and its application to the PAC-3 program. Some of the initial questions were:

- How should military or commercial standards and components be utilized in developing and building the PAC-3 missile?
- What commercial practices should be used or how should MIL-STDs be tailored?
- How extensive should the Government's deliverable data requirements be?

There were, of course, many other related questions that came up as the various Requests for Proposals were being developed and in subsequent negotiations with industry. **The key ingredient for any successful streamlined process is the contractor's commitment.** The PPO has found that working with the contractor has resulted in satisfactory resolution of the many questions that have arisen.

The positive result of acquisition streamlining was that both the Government and industry had to work smarter, be more efficient, use integrated product teams, and accomplish more with less. Thus, it was incumbent on the Government to rethink its philosophy of how business will be conducted with industry. This philosophy may be summed up as follows:

- |                        |                                                                                                                  |
|------------------------|------------------------------------------------------------------------------------------------------------------|
| • Think.               | Give consideration to every possible alternative.                                                                |
| • Use common sense.    | Do the right thing correctly at the right time.                                                                  |
| • Use lessons learned. | Do not repeat the mistakes of the past and capitalize on AMCOM's and PEO-AMD's excellence in developing missile. |
| • Be creative.         | Allow the contractor to use ingenuity to complete the program objectives.                                        |

To date, the PPO, along with its contractors, has been successful in applying this philosophy in addressing the challenges of acquisition streamlining. The future will require both the Government and industry to work together as a team to assure that the final product reliably performs as prescribed and is as cost effective as possible.

#### **IV. OVERALL APPROACH**

Between the government and the contractor, an approach was developed under the streamlining guidelines to ensure all product assurance elements were planned for. These elements include:

- 30-year deployment scenario
- Reliability requirement/allocations/predictions
- Design criteria
  - Failure modes/mechanisms/component de-rating
- Manufacturing/Quality
- Testing
  - Failure data collection/analysis/corrective action
- Verification
  - Reliability models/reliability growth program
  - Field Surveillance program

These elements will be documented as they are completed. Further amplification of these elements are addressed in the following paragraphs.

##### **A. 30-Year Deployment Scenarios**

Since the expected deployment life of the PAC-3 missile is 30-years, a time line was established to determine the various external stresses that the missile would expect to experience during its life. The time line was correlated with tactical scenarios that included flight, transportation/on-launcher, and long-term storage. The flight portion assessed the missile at approximately twice the actual stresses anticipated. For transportation (common carrier and tactical transport on the launcher), the contractor conducted an extensive transport vibration test program (a pre-PAC-3 early road mobility test with the launcher and GMT) using the road course test tracks at Redstone Arsenal. Using that test data and vibration analysis, a transportation environment was derived to encompass the transportation life scenario specified in the system specification for a 30-year life. Also, using historical environmental data a realistic temperature profile for the 30-year life cycle was generated. The key to this profile is that it is very closely tied to the ORD geographic deployment locations.



## **B. Reliability Requirements/Allocation/Prediction**

Reliability requirements were based on PATRIOT's past experience, the related experience of similar missile systems, and the mission requirement. This combined experience, coupled with knowledge of the advanced technologies that are incorporated into the PAC-3 missile, resulted in a missile reliability requirement which was higher than the PAC-2 missile. This reliability value was allocated down to the various subsystems as a function of complexity and expected environments (storage, on-launcher, and in-flight). As part of the Critical Design Review (CDR) process, a reliability prediction was developed based on the design data. The predicted reliability was consistent with the requirement.

To address the 30-year time line, a plan is being formulated to expose or analyze PAC-3 missile peculiar components produced during Low Rate Initial Production to a limited storage test program that simulates the mission environments. The selected items and tests were developed considering program constraints. Among the items to be tested/analyzed are the traveling wave tube, wet box transmitter, master frequency generator, and others. This approach, along with the overall Product Assurance architecture (environmental stress screening, appropriate critical processes, failure reporting and corrective action system, conformal coating, corrosion prevention, and others) will provide a high probability that the PAC-3 missile will achieve its expected performance and reliability over the 30-year expected life.

## **C. Design Criteria**

The design criteria imposed on the contractor include the following:

- The parts and materials are being selected in accordance with a contractor document entitled, "Parts, Material, and Processes (PMP)." This document was derived from military standards and AMCOM/PEO-AMD/contractors 30 plus years of missile experience.
- The experience gained from missile systems currently managed by AMCOM and PEO-AMD will be used in the selection of parts/material/processes to assure commonality where possible and to capitalize on lessons learned.
- Sneak circuit analysis will be performed on ordinance related circuits to ensure no hidden fault paths exist.
- Failure modes/mechanisms analysis will be performed and the physics of failure will be considered for improving reliability.
- Quality requirements for hardware will be specified as the hardware designs are finalized. These requirements will be part of the manufacturing process to ensure a quality product is produced. During missile production, statistical process control will be used to assure that all manufacturing processes will remain within those quality limits.

#### **D. Testing/Verification/Processes**

Testing will start at the component/subassembly level and end with full missile tests to include the canister. As a minimum, the type of tests planned are:

- Environmental Stress Screening (ESS)
- Environmental Qualification Tests, Stockpile to Target Tests, etc.
- Nuclear, Biological, and Chemical assessment/verification
- Safety

These tests will be structured to ensure all requirements of the missile segment specification and its lower tier specifications are verified and that hardware/software meets all requirements identified in these specifications. During the conduct of each of these tests, failures will be fully documented and failure analyses conducted to determine causes of the failure. When appropriate, corrective action will be instituted to remove or mitigate the cause of failure.

#### **E. Verifying Reliability Requirement**

Because the deployed life of the PAC-3 missile is anticipated to be up to 30-years, it is imperative that the reliability degradation rate and performance be continuously verified during its fielding. The PPO has established two programs which will provide the basis for verification of the PAC-3 missile's life-time reliability and performance. One of these programs will use models to predict and provide confidence in the missile's reliability. The other is a Field Surveillance Program which will provide "real" field data to help establish trends, determine the rate of reliability degradation and identify any shifts in performance parameters.

##### **1. Reliability Models**

The number of full system flight tests planned for the PAC-3 system are insufficient, in and of themselves, to provide high statistical confidence in system reliability. Confidence in missile reliability is obtained from test results that demonstrate the missile works as intended. Test results have historically been obtained from flight tests. However, there are other sources of testing results evidence that can and will be utilized when the number of flight tests are small. Various types of ground tests on missile subsystems and components can provide evidence of total missile reliability. Data available from other missile systems or components used directly within the PAC-3 missile can also provide the needed statistical data. Also, data on total missile systems, which are similar to the PAC-3, will be used.

The PPO has undertaken the development of the Expanded Confidence Assessment Process (ExCAP) methodology. It is an expansion of the classical theory whereby the tools from the field of uncertainty management systems are used to accomplish this expansion. The ExCAP model will support reliability assessment/verification for the PAC-3 missile. The model is currently under evaluation to determine its validity and suitability to the PAC-3 missile application.

Additionally, the U. S. Army Materiel Systems Analysis Activity (AMSAA) has system and subsystem reliability tracking models that utilize classical statistical approaches. The system tracking model is being used by the U. S. Army Evaluation Center to assess the maturity of the subsystems over time through reliability growth analyses by treating each subsystem in the missile as an individual system. The model then provides an estimate of the reliability growth and demonstrated reliability that has taken place for that subsystem. Then the same data from all subsystems is inputted into the subsystem tracking model which then calculates a reliability estimate for the missile. The analyses are continuously updated as more data becomes available.

Other possible analytical/statistical approaches to validating system reliability are also being reviewed and considered. This includes the application of goal programming to evaluate the trade-off between cost, reliability, stockpile reliability testing, and the number of recertifications. Also, the application of linear signal processing to reliability evaluations is being explored. Development of this technique has the potential of considerable cost savings, through elimination of guess work from testing.

## 2. Field Surveillance Program

The PAC-3 missile is a certified round. A certified round has a predictable and acceptable level of reliability degradation over a specified certification period. During this period it is maintenance free (excluding minor repairs such as paint touch-up, for example). While it is in storage, a periodic assessment of a statistical sample during the certification period will evaluate and confirm the reliability characteristics. Controlled testing and replacement of degraded items will be required at the end of the certification period to retain the missile in a serviceable condition and to ensure its continued high reliability and performance.

Because of the nature of the certified round, a field surveillance program is being developed that is modeled to mirror the successful PAC-2/Basic PATRIOT field surveillance program. This program will include:

- a. Stockpile Reliability Test. Based on statistical sampling theory, missiles will be sent to a facility (depot or factory) for functionality tests, physical integrity inspections, and other tests.

- b. Certified Round Data Management Database. This database will provide traceability of each missile. It will in essence be the history of each missile, documenting initial components, missile certifications, and failed or replaced components. This database will be used to establish and track trends.

- c. Storage and Aging Program. Selected components will be stored in various global environments such as hot (South West Asia), cold (Alaska), humid (Panama), and a basic benign environment. Data from periodic testing will be used to establish and track trends.

d. Missile Firing Program. Lot validation firings will be conducted to ensure quality missiles are entering the stockpile. Surveillance firings will be conducted to verify performance parameters, detect trends, and analyze drifts in critical parameters prior to arriving at an out of specification condition. The Field Surveillance program will be the primary provider of information that will assure the PAC-3 will be ready for use and in a highly reliable state at any time it is needed.

## **V. CONCLUSION**

The PPO continues to meet the challenge of designing, producing, and fielding a highly reliable hit-to-kill missile. Driven by the changes brought on by acquisition streamlining, the PPO, Lockheed Martin Vought Systems, and Raytheon have formed a partnership to assure that a quality, highly reliable missile meeting all performance requirements is produced. Continuing success will require intensive management of this program. The reliability requirements have been established and the loads/stresses/environments the PAC-3 missile will be exposed to have been identified. From this basis, the PPO is putting together the necessary tools and programs needed to ensure that the PAC-3 missile is reliable, meets all requirements, and will remain so over its 30-year lifetime.

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